Enhanced LSST weak lensing via combination with external ~~spectroscopic~~ datasets

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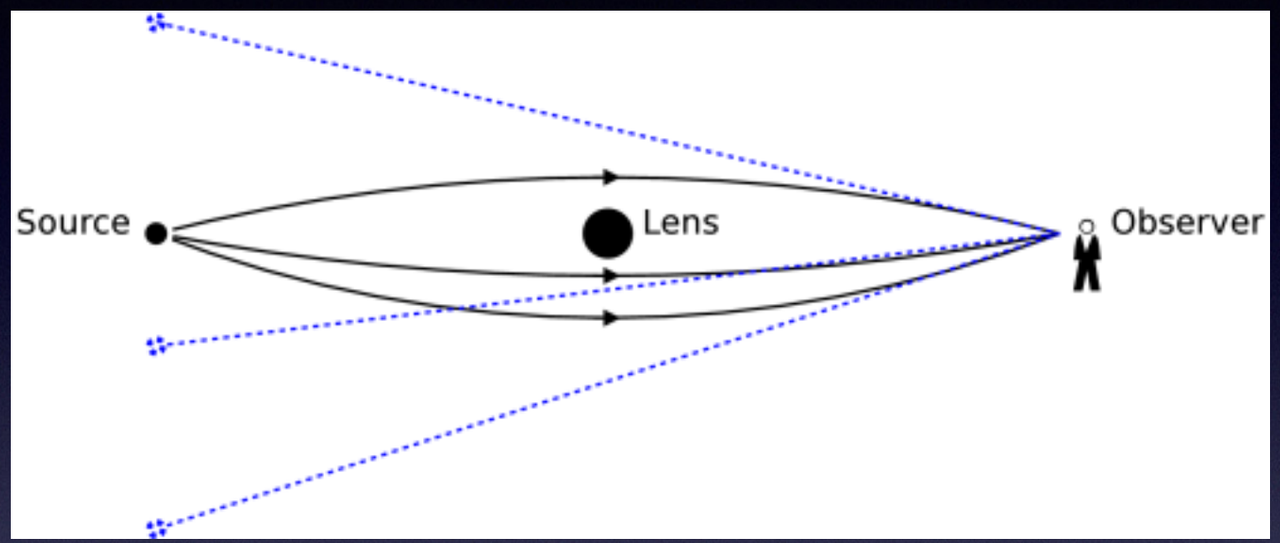
5/23/2016

Outline

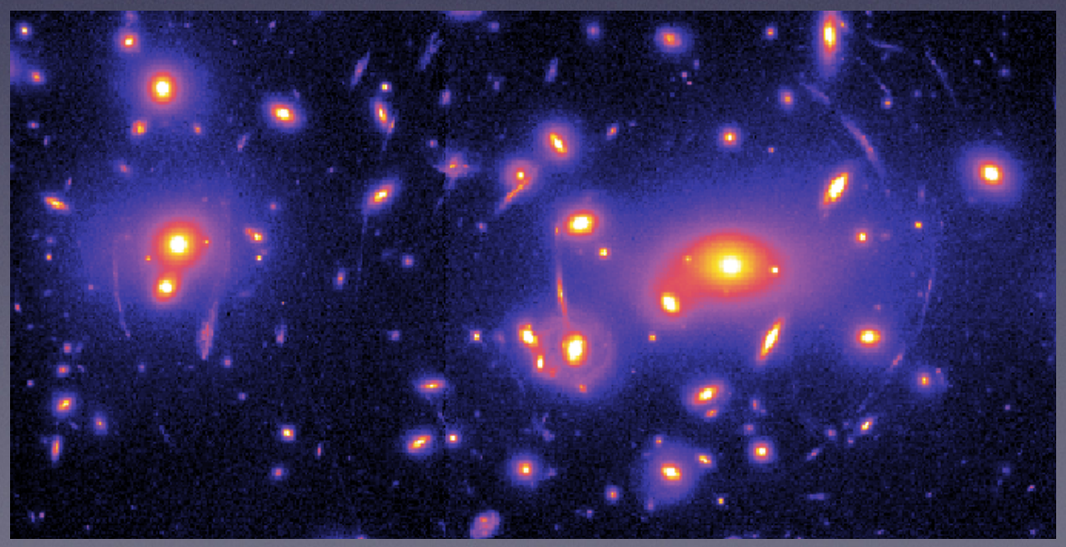
- Background
  - Weak lensing science
    - The case for cross-correlations
- Cross-correlation with spectroscopic datasets
- Cross-correlation with the CMB

Gravitational lensing



Deflection of light by all gravitational mass, including dark matter!

Strong:
multiple images



Gravitational lensing

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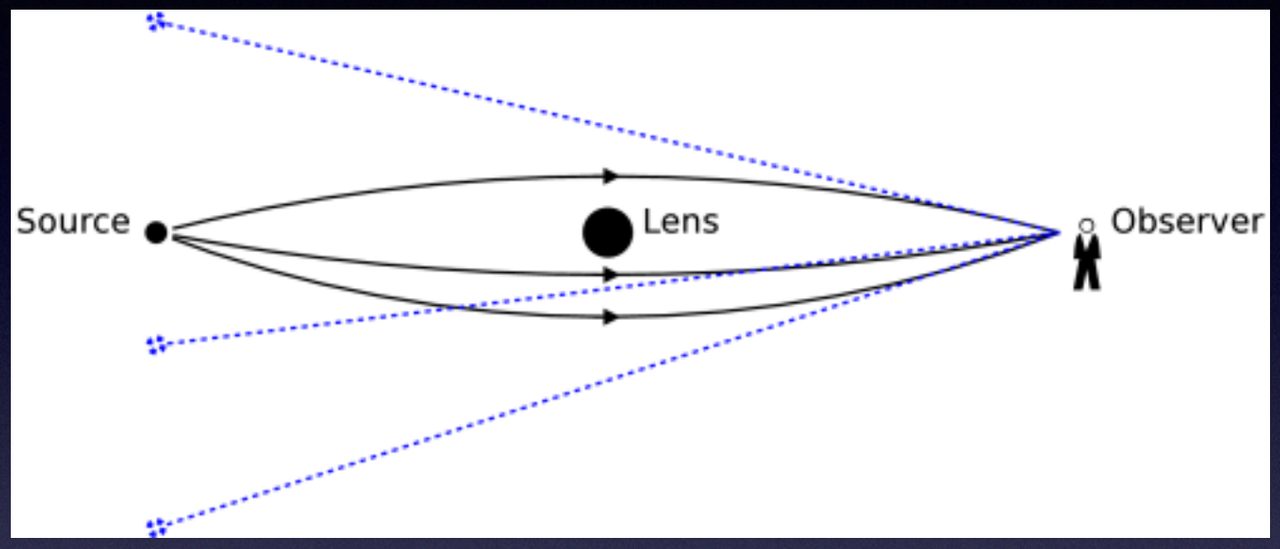
Gravitational lensing



Strong:
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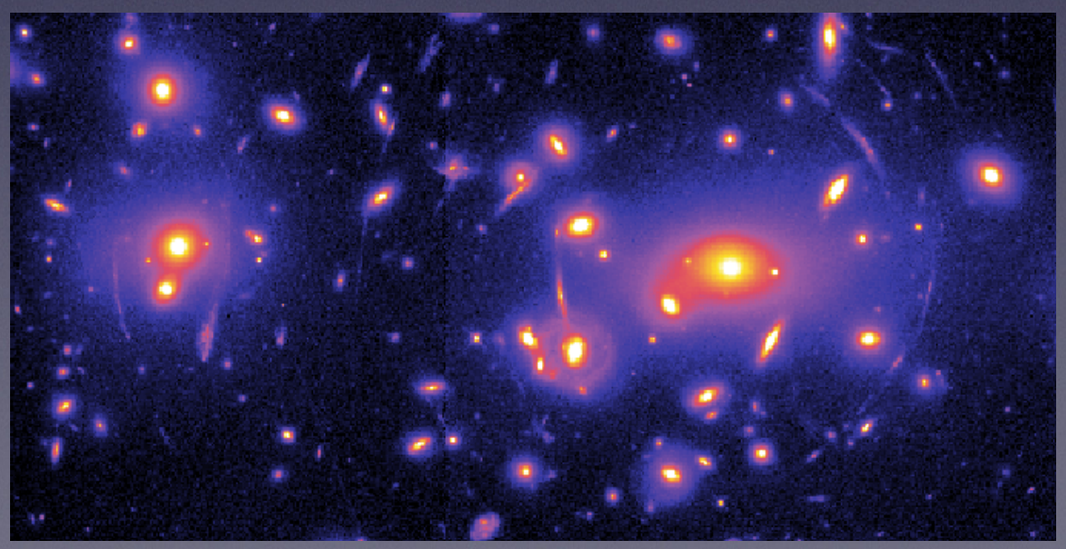
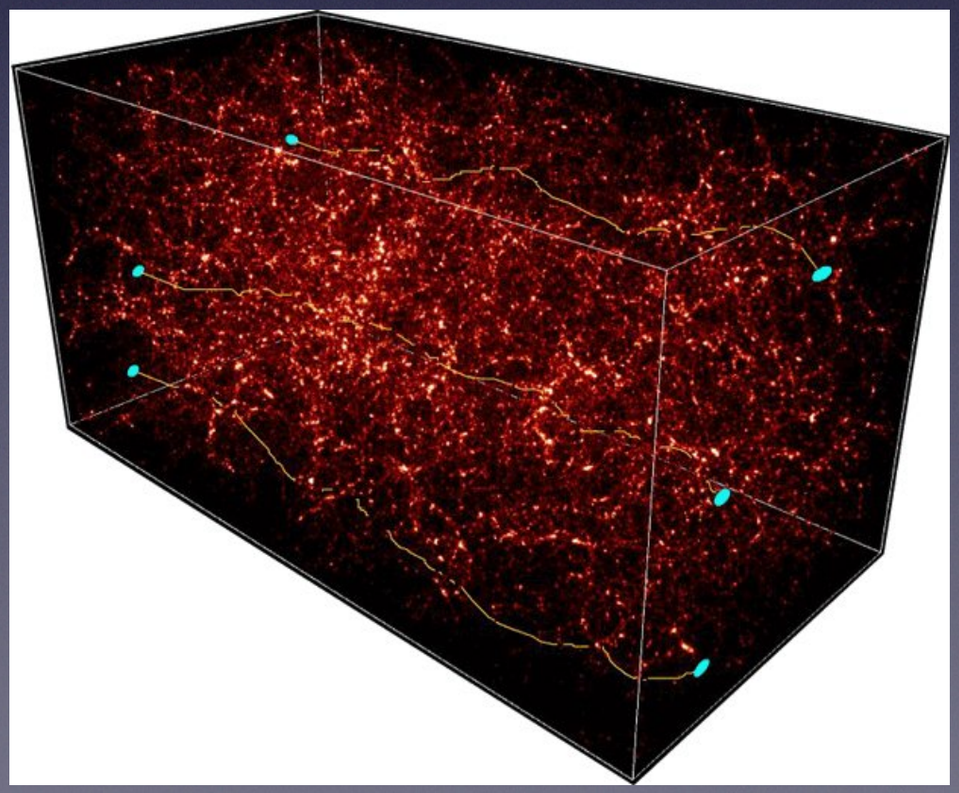
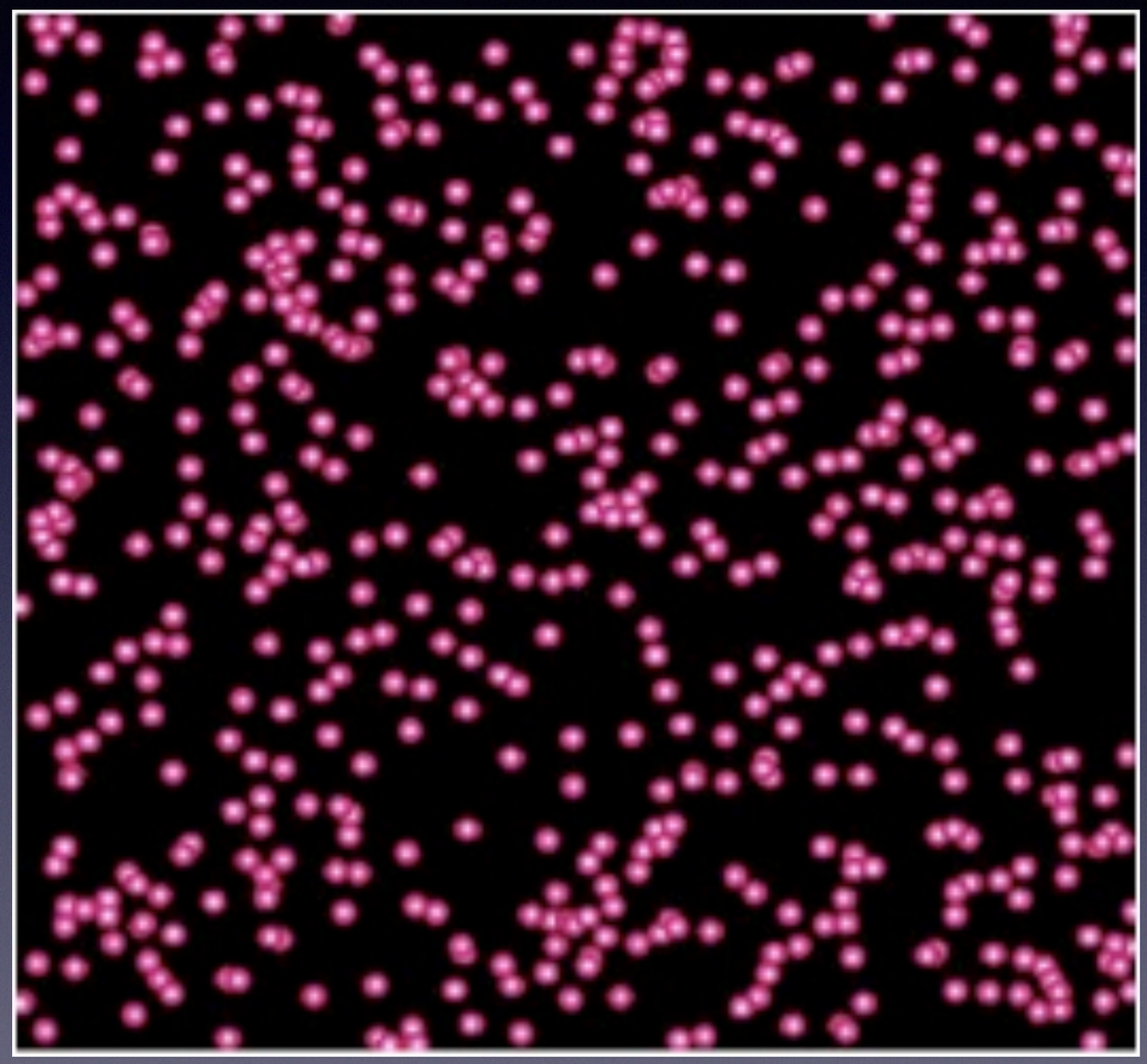


Deflection of light by all gravitational mass, including dark matter!

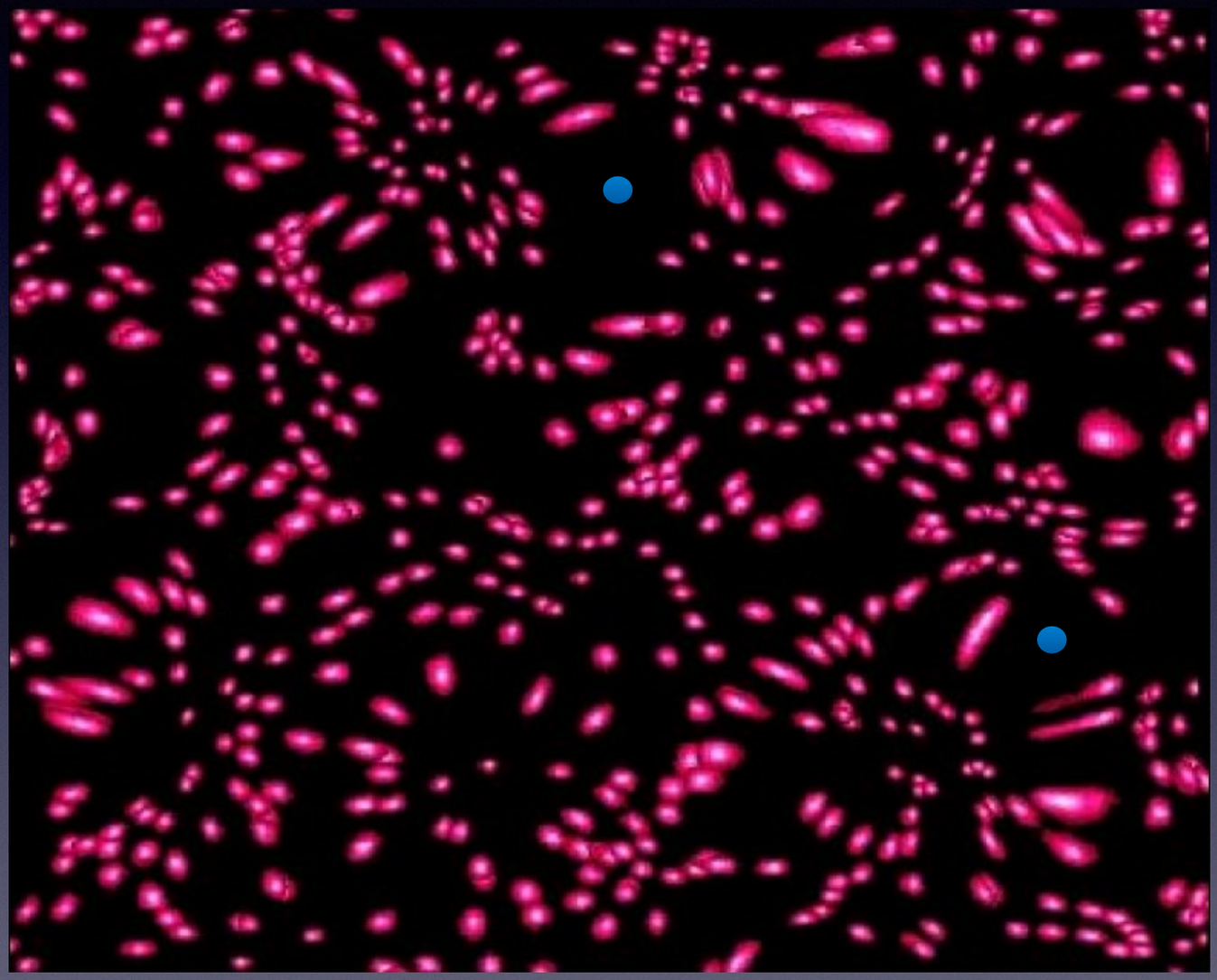
Weak: slight shape distortion and magnification



Weak lensing



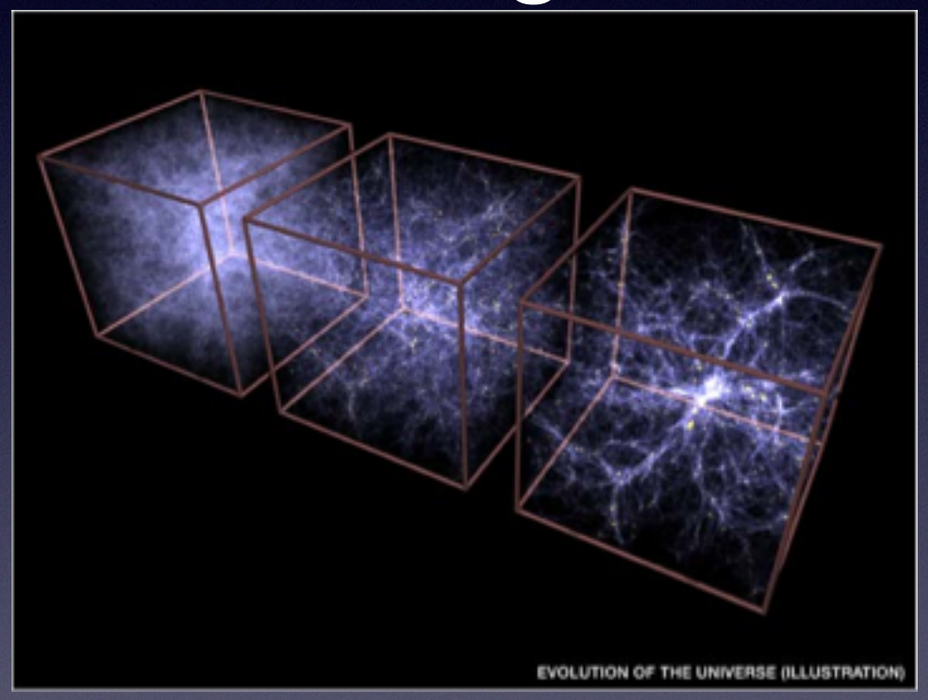
Weak lensing



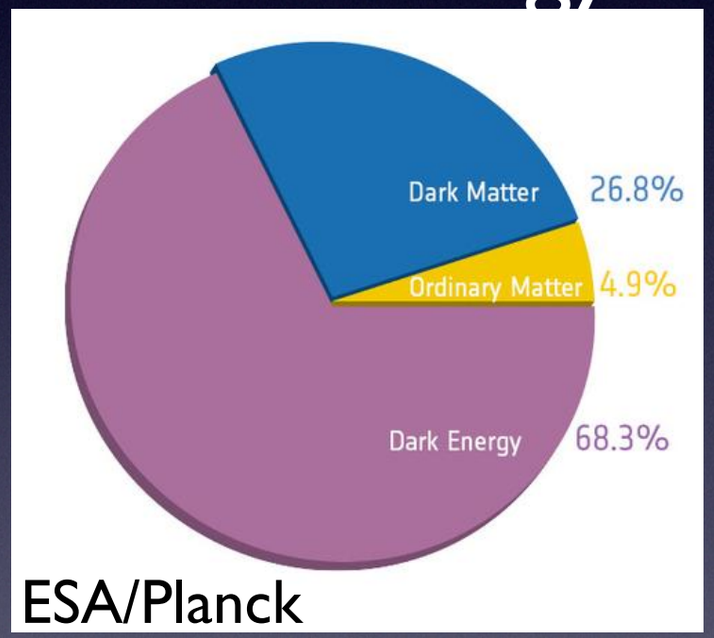
Coherent shape-shape (shear-shear) alignments
OR
Coherent foreground position-background shape alignments

Why should you care about weak lensing?

Structure growth!



Dark matter and dark energy!



ESA/Planck

Theory of gravity!

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = 8\pi G T_{\mu\nu}$$

Galaxy-dark matter connection!

Weak lensing in the era of LSST

Starting in 2003: shear-shear (cosmic shear) got lots of attention

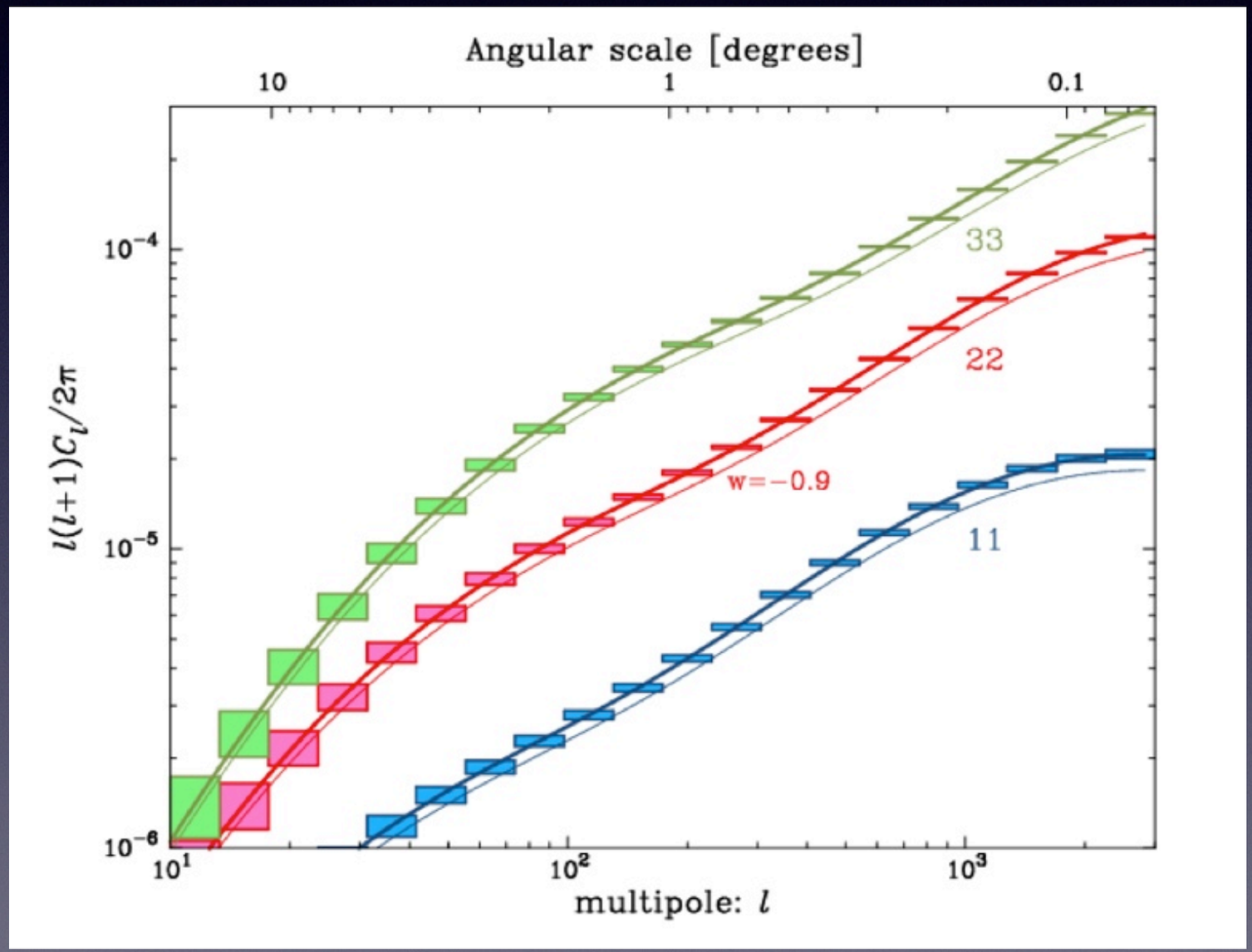
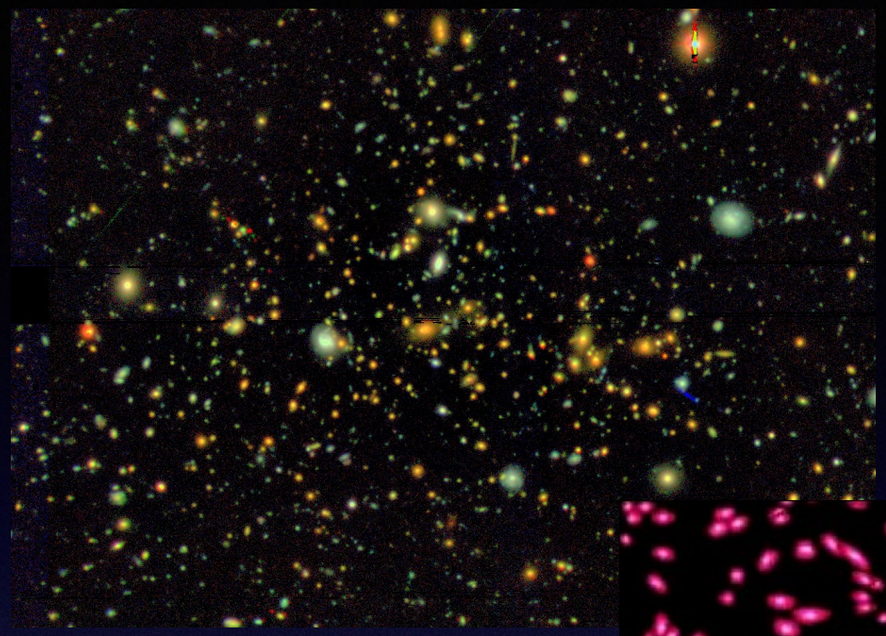
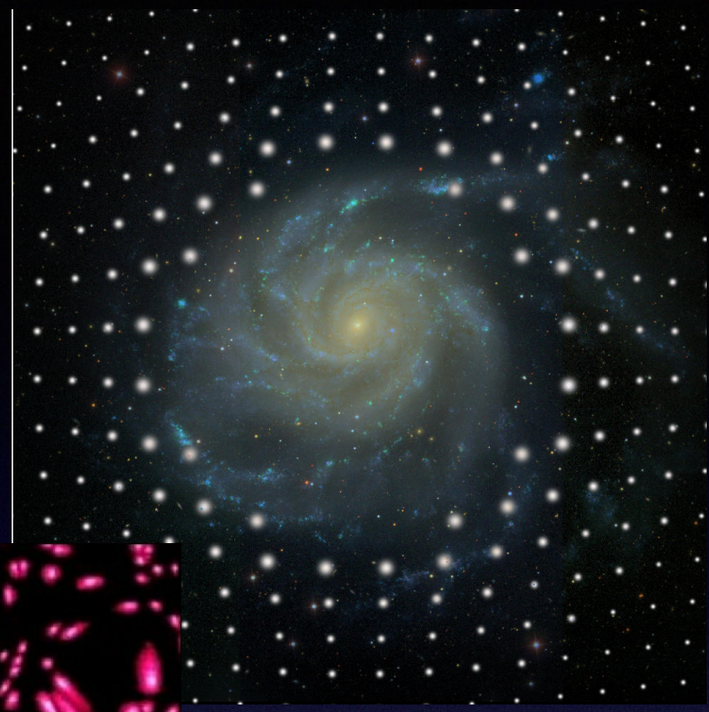


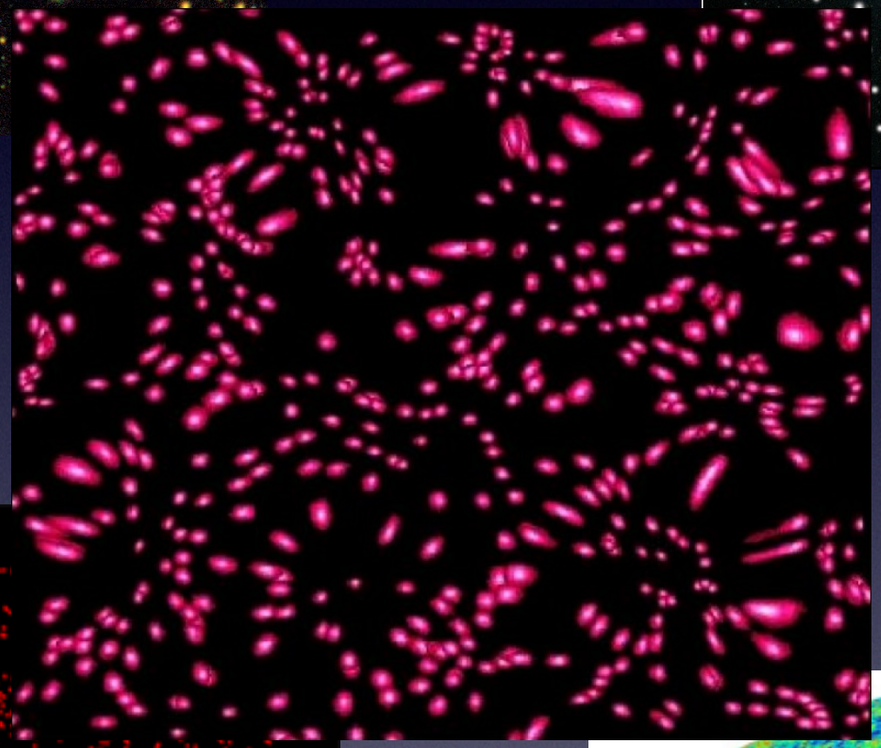
Image credit: LSST science book



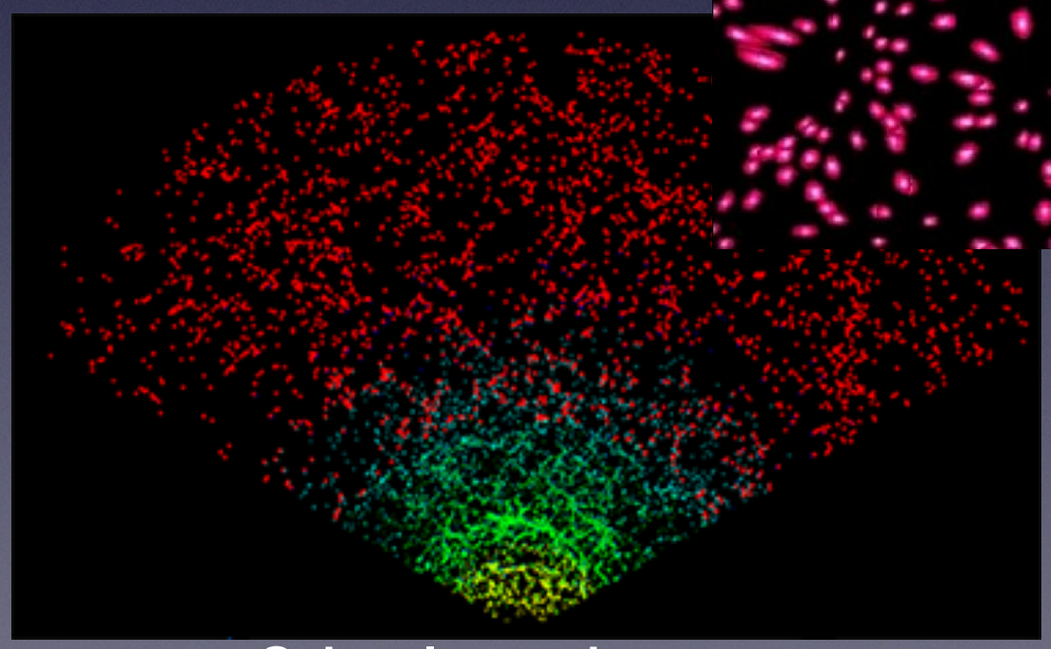
2d (2+1d?) galaxy density field



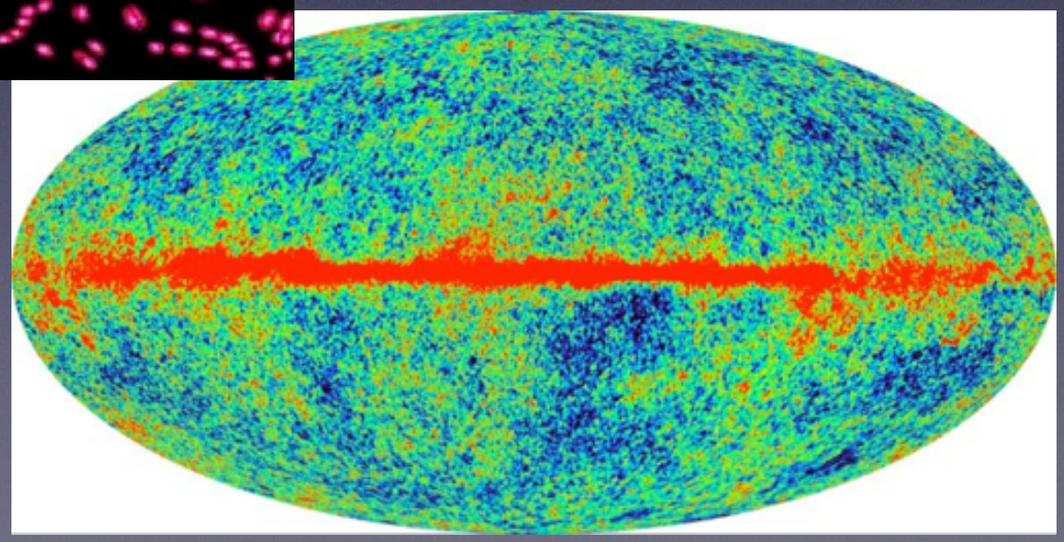
Lensing magnification



Lensing shear



3d galaxy density + peculiar velocity field



Cosmic microwave background

Why do we want
that other stuff?

It's all about the
systematics

Example (schematically)

1. shear-shear
2. OTHER-shear
3. OTHER-OTHER

If a systematic is in shear, but not OTHER ⇨ use the combination to marginalize over the systematic

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If a systematic is in shear, but not OTHER ⇨ use the combination to marginalize over the systematic

- Systematics: theoretical or observational
- OTHER: galaxy position is a popular one

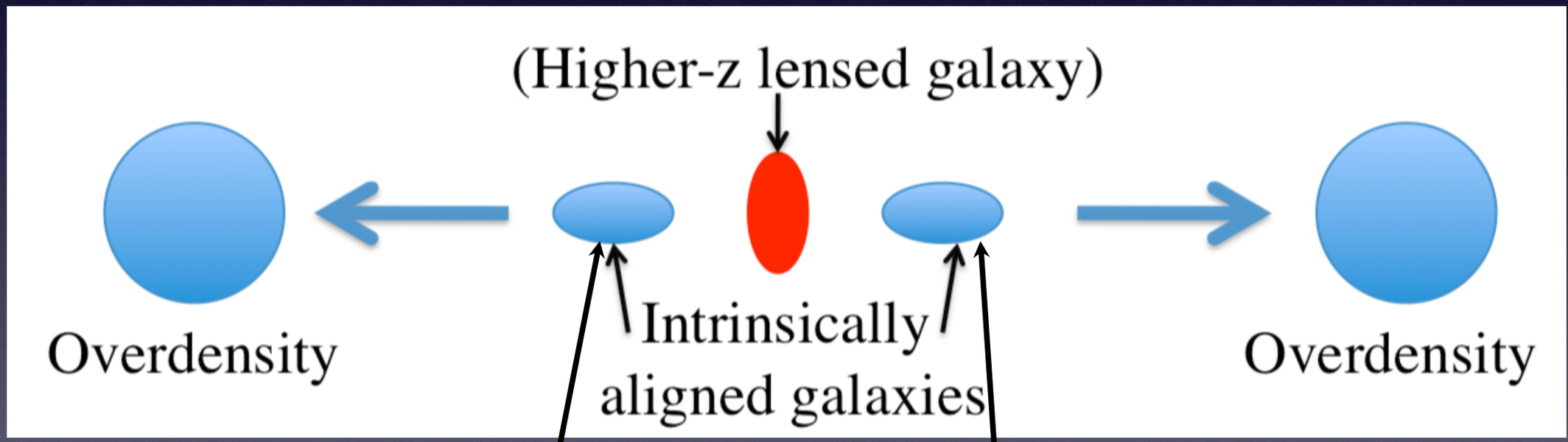
Spectroscopic cross-correlations

Photometric redshifts

- Interpreting weak lensing shears as a function of cosmological parameters requires a knowledge of distances
- Use of spectroscopic cross-correlations to calibrate photometric redshift distributions: see Jeff Newman's talk

Intrinsic alignments

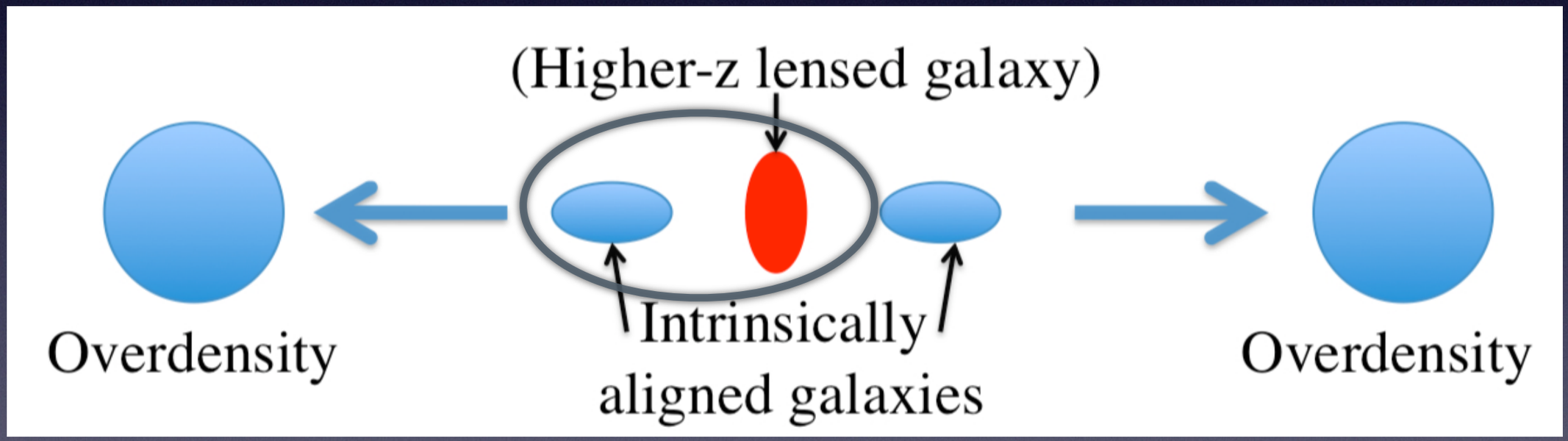
Coherent shape alignments due to effects rather than lensing



Correlate these: “II” term
(intrinsic shear - intrinsic shear)

Intrinsic alignments

Coherent shape alignments due to effects rather than lensing



Correlate these: "GI" term
(lensing shear vs. intrinsic shear)

Effect on lensing measurements

- Can give huge biases on cosmological parameter estimates if ignored!
  - See, e.g., Krause+15

➡ Need to marginalize over intrinsic alignments

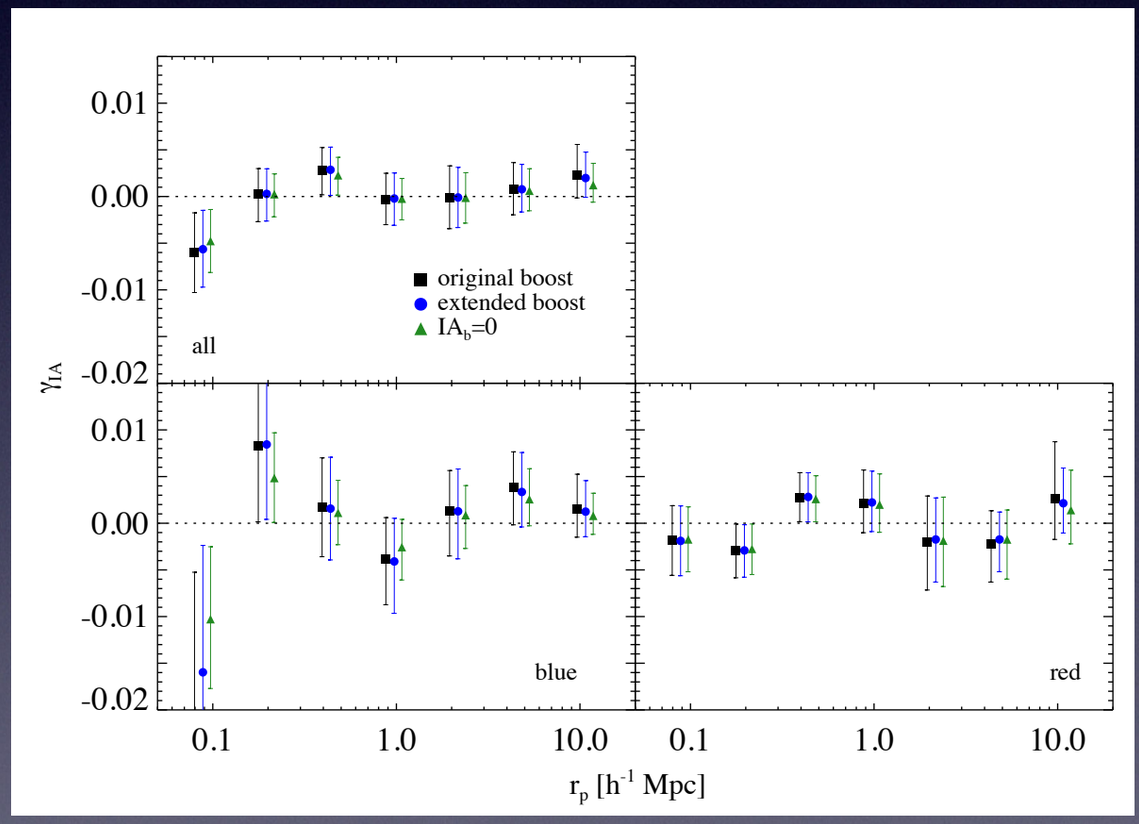
- shear-shear
- Galaxy position (2d)-shear
- Galaxy position (2d)-galaxy position (2d)

How do we get models?

- Analytic models, N-body or hydrodynamic simulations provide models
- Direct measurements of intrinsic alignments provide priors
  - Ideally use spec-z to reduce degeneracies with redshift errors
  - Can use either a representative spec-z dataset, or an un-representative one in cross-correlation

Cross-correlation method

- Blazek et al (2012), Chisari et al (2014)
- Compare shear from associated and background galaxy
- Allows non-parametric IA constraints using spec-z tracers of the density field



A cosmic shear alternative / consistency check?

Connection to the matter field

- shear-shear ⟶ Matter-matter correlations

- Galaxy-shear ⟶ Galaxy-matter
- Galaxy-galaxy

$$\frac{(\overline{\rho}\,\xi_{\rm gm})^2}{\xi_{\rm gg}} = (\overline{\rho}\, r_{\rm cc}^{(\xi)})^2 \xi_{\rm mm}$$

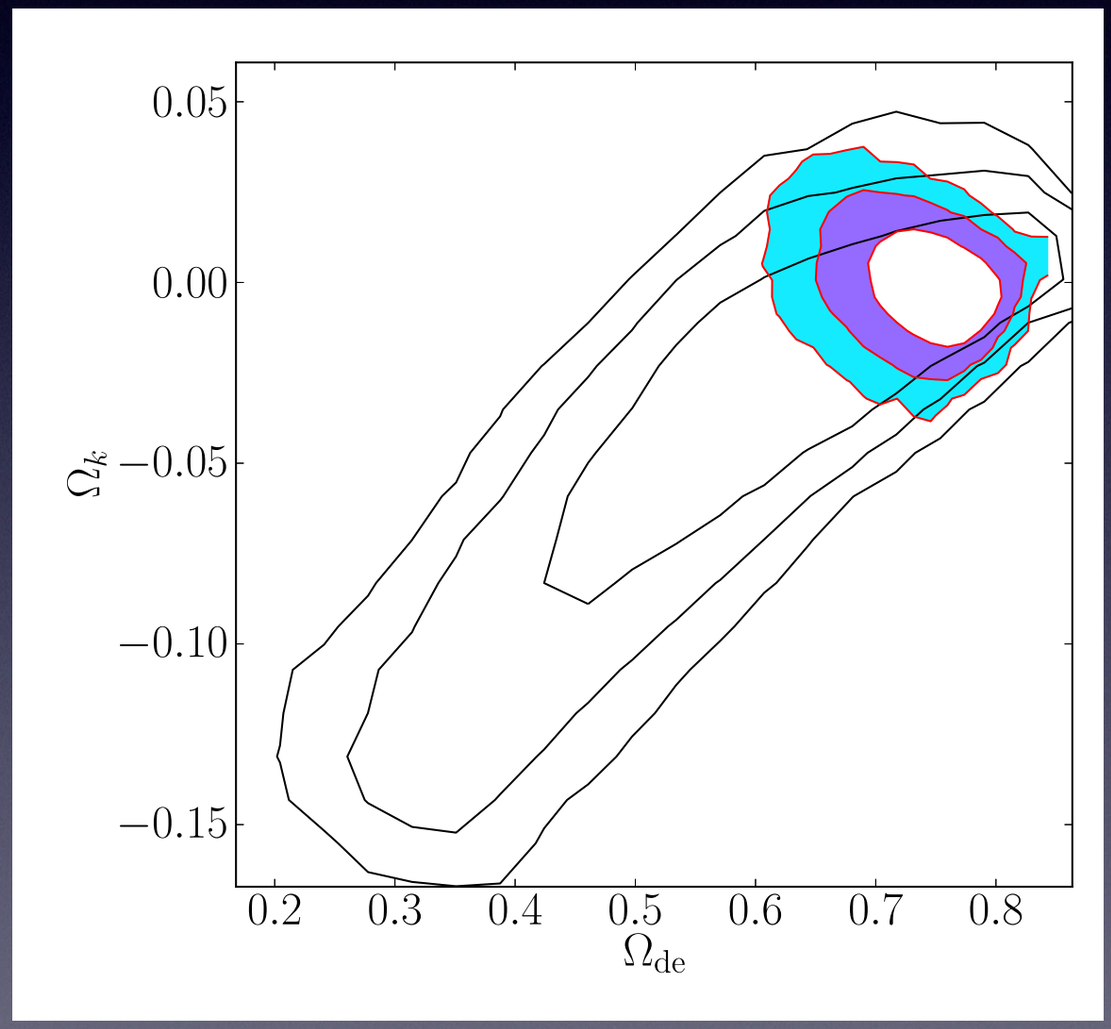
Cross-correlation coefficient between galaxies, matter: generically goes to 1 on large scales

Why?

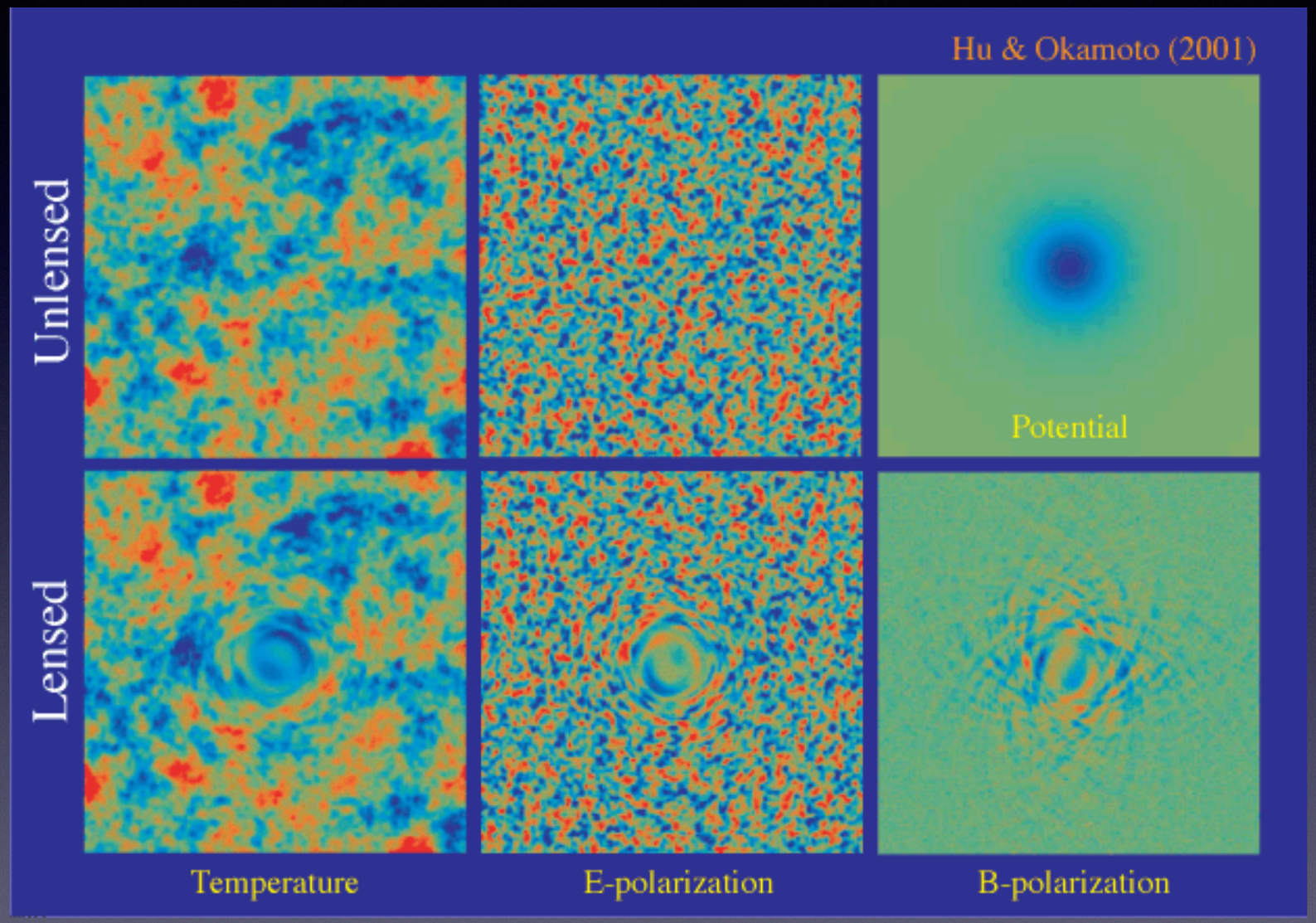
- We often know lens redshifts quite well for massive objects (lots of cosmological info)
- Use of real-space separation (not angle) makes it easier to marginalize over small scales that we cannot easily model
- Some shear systematics vanish in cross-correlation, not auto-correlation
- Intrinsic alignments only enter due to photo-z error

Proof of concept

- RM+13 demonstrated method in SDSS (too shallow for cosmic shear)
- Constraints on dark energy were competitive with cosmic shear in other datasets
- Updated analysis in preparation…



CMB cross-correlations

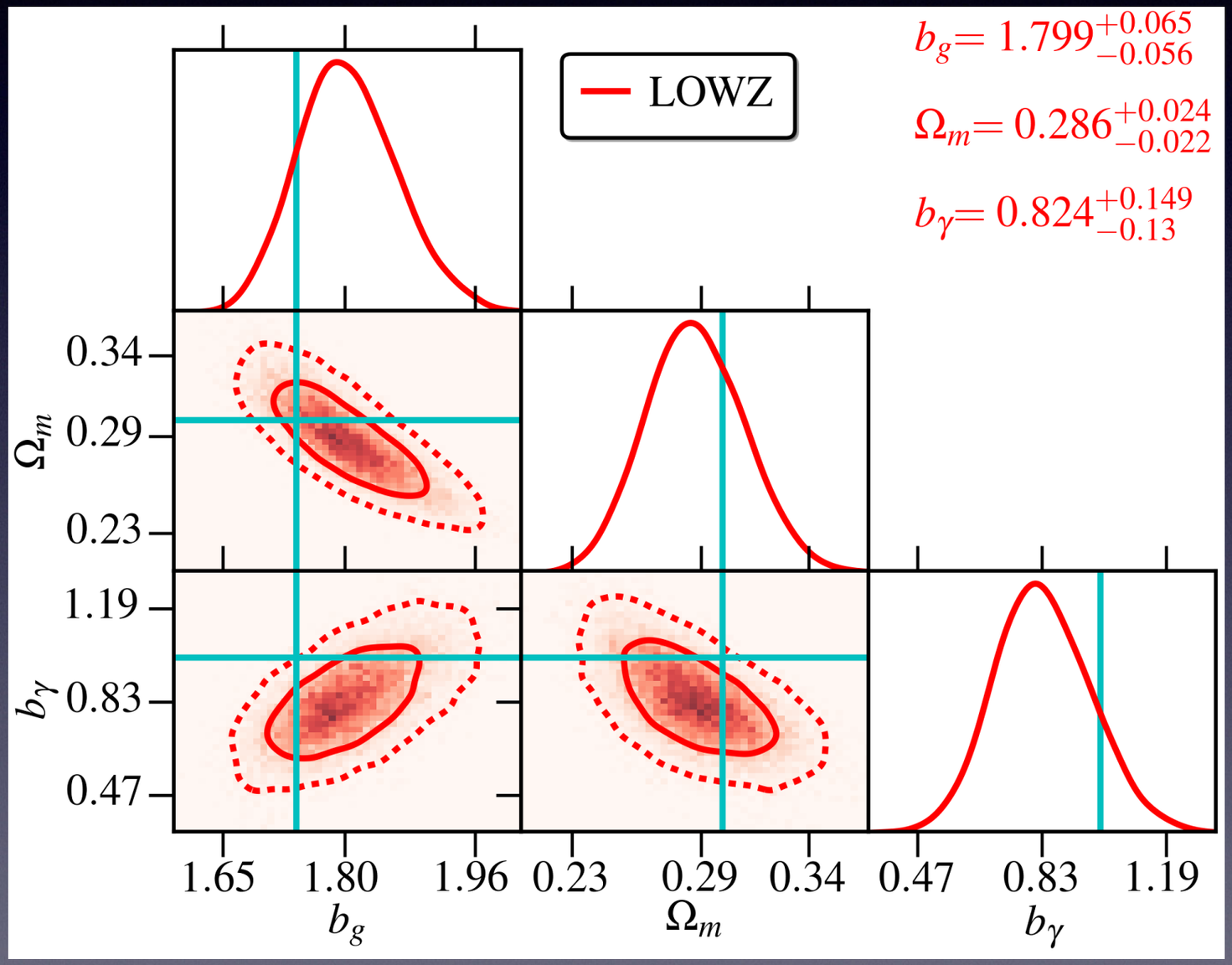

Hu & Okamoto (2001)
Unlensed
Lensed
Potential
Temperature
E-polarization
B-polarization

What cross-correlations are useful?

- Galaxy position – galaxy position ⟶ Galaxy bias
- Galaxy position – lensing of galaxies
- Galaxy position – lensing of CMB
- (and more)

Proof of concept in SDSS

See Jia Liu's talk later today for CFHTLenS example



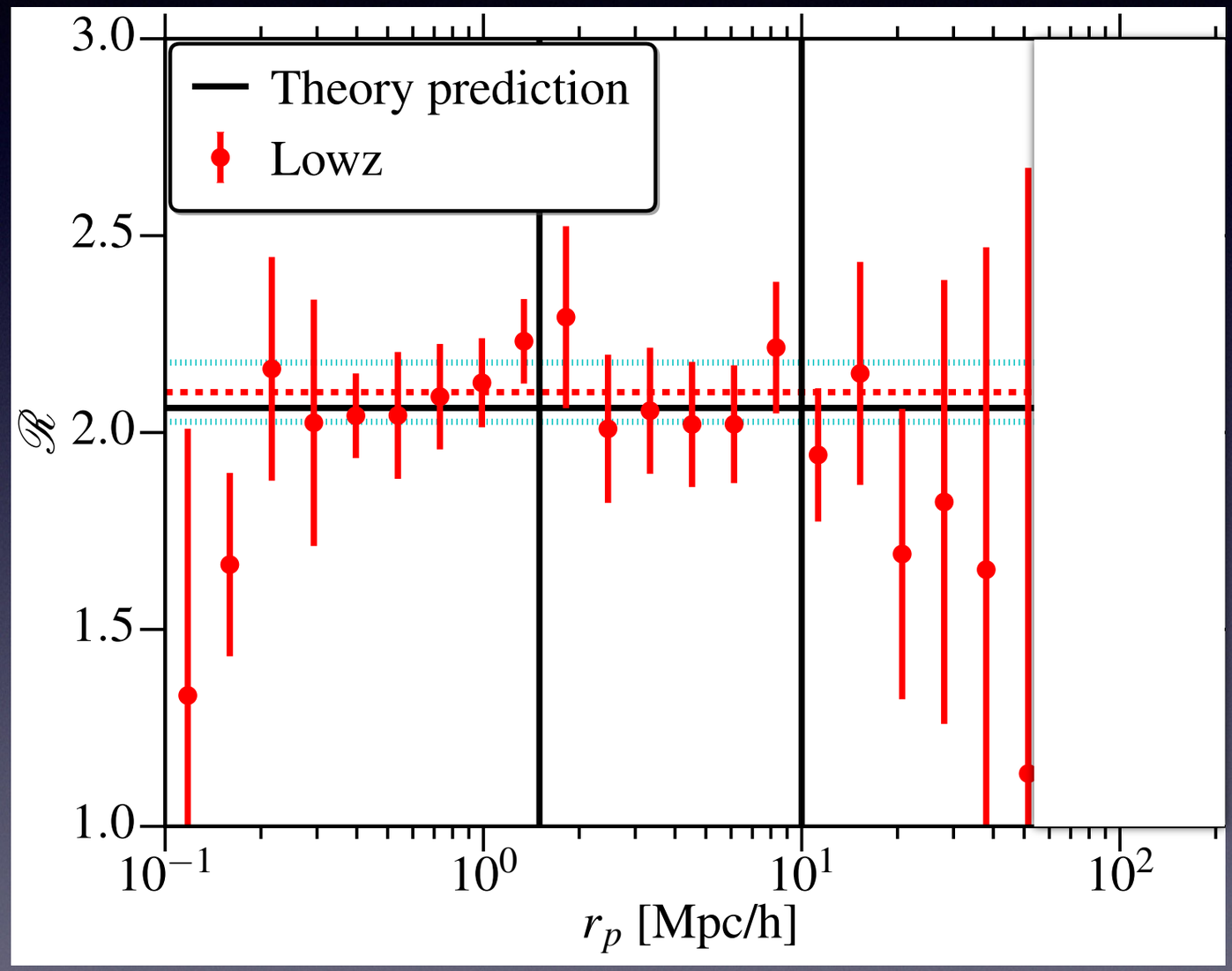
Singh & Mandelbaum (in prep)

Also: cosmography

Distance to CMB

Distance to galaxies

See also
Miyatake
et al. paper
from last week



Singh & Mandelbaum (in prep)

Expect rapid progress in this area

- Initial CMB lensing detections and cross-correlation with galaxy lensing shear – not too long ago!
- Should be a high-interest area in the next few years
- Watch CMB-S4 plans…

Conclusions

Approach to lensing in the era of LSST:

Cross-correlate everything.